

PATENT APPLICATION

NAVY CASE NO. 83166

**APPARATUS AND METHOD FOR FIN ACTUATION IN A PORTABLE MISSILE****STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR  
DEVELOPMENT**

5           The invention described herein may be manufactured and used by or for the government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

**FIELD OF THE INVENTION**

10           The present invention relates generally to flight control actuators and more specifically, to fin actuators that substantially limit backlash in portable missiles while meeting strict construction constraints.

**BACKGROUND OF THE INVENTION**

15           In today's conflict scenarios the warfighter must be versatile and on the move. More often munitions and weapons are required to be man packable and portable. Funds for warfighting are stretched to their fullest, adding the requirement of lower unit cost. One alternative that meets these requirements includes a man packable, portable, and economical shoulder launched missile. In order to be man portable the missile must be lightweight and compact.

20           One specific area of concern in the construction of a portable missile is the operation of the fins or wings. Missile control fins are commonly positioned by actuators mounted within the missile body in an actuator section. The actuator exerts appropriate rotational torque and control on

the fin in response to commands from the guidance control system to maneuver the missile. In a portable missile, there exists for a fin actuator stringent requirements of size, weight, torque and angle of deflection delivered to the fin shaft, backlash, cost, and ease of construction. The small body diameter requirement intensifies the mechanical problem of converting rotary motion from a motor into torque to be applied to a fin shaft. In addition, all of the missile components must withstand great temperature variations due to their shipment and use in many different climates.

Total backlash refers to the additive “slop” or “play” that exists between the mating components in a fin actuator, measured as a total angular value at the fin shaft as the fin or wing rotates about its axis. The various backlash values of the components contribute to the overall total backlash. Friction between components and thermal expansion contribute to total backlash. An excessive amount of backlash in the fins or wings creates a situation in which directional control of the missile is much more complicated for the guidance control system.

Many types of conventional fin actuators were examined to meet the fin actuator requirements. A worm gear drive small enough to meet the demands of the missile would require custom manufacture of the gears, and since there is inadequate room to fully support the worm gear a large amount of friction would result. It would be difficult (costly) to manufacture a worm gear to meet the physical space requirements. A bevel or miter gear actuator must be set, preloaded and shimmed to maintain the proper clearances. Also, gears are subject to expansion and contraction with temperature, contributing to backlash. In a production environment, positioning gears to achieve correct spacing is difficult, contributing to the cost. Custom fabrication and assembly would be required for this type of actuator, thereby exceeding the cost and ease of fabrication requirements. The use of a stepper motor linear actuator was also precluded due to the dimensions

of the motor. In addition, these drives do not accommodate significant side loads that can be generated while in flight. Hydraulic type actuators also exceeded the physical space requirements. In general, the final result in the actuators considered was an excessive amount of backlash, along with difficulty meeting size and weight parameters.

- 5           Therefore it would be desirable to provide a fin or wing actuator that will meet the specific requirements previously discussed for a low cost, man-portable missile.

### **SUMMARY OF THE INVENTION**

10           The present invention relates to a novel fin actuator for a portable missile and a method of using the same. One aspect of the present invention includes a fin or wing actuator that meets very strict criteria to fit within a compact, portable missile while substantially limiting backlash. Another aspect of the present invention is a method of fin actuation in a portable missile while substantially limiting backlash.

15           An embodiment of the present invention a fin actuator(s) in a portable missile that substantially limits backlash includes a means for rotating a power shaft operatively configured to rotate the power shaft in a forward direction and a reverse direction; a means for converting the rotational movement of the power shaft to linear movement, including a lead screw fixedly coupled to the power shaft with a lead nut threadingly engaged and moving linearly along the lead screw in relation to the direction of rotation of the power shaft; and a means for converting the linear  
20           movement of the lead nut to rotational movement of a fin shaft, including the lead nut operatively coupled to a crank arm fixedly coupled to the fin shaft, effecting the rotation of the fin shaft according to the linear movement of the lead nut.

Another aspect of the present invention includes a method for fin actuation, in a portable missile, that substantially limits backlash. An example of the method includes but is not limited to, providing a means operatively configured for rotating a power shaft in a forward direction and a reverse direction, providing a means for converting rotational movement of the power shaft to linear movement via a lead screw fixedly coupled to the power shaft and having a lead nut threadingly engaged moving linearly along the lead screw in relation to the direction of rotation of the power shaft, and providing a means for converting the linear movement to rotational movement of a fin shaft, including operatively coupling the lead nut to a crank arm that is fixedly coupled to the fin shaft, effecting the rotation of the fin shaft according to the linear movement of the lead nut.

In an embodiment of the present invention the lead screw, lead nut, and crank arm are so constructed and coupled as to limit the total backlash of the actuator(s), measured at the fin shaft, to less than about 0.1 degrees. In additional embodiments of the present invention the actuator(s) is dimensioned and configured to fit in a portable missile of less than about 5 lbs, of less than about 2 inches in diameter, and/or of less than about 3 inches in length. In additional embodiments of the present invention the actuator(s) is providing at least about 50 oz-in of torque to the fin shaft and/or providing from at least about -20 degrees to at least about +20 degrees of deflection of the fin shaft. In another embodiment of the present invention the actuator(s) includes the crank arm and the fin shaft combined as a unitary structure. It is noteworthy that multiple embodiments of the present invention shall be used to operate multiple fins on a portable missile.

It is to be understood that the foregoing general description and the following detailed description are exemplary and explanatory only and are not to be viewed as being restrictive of the present invention, as claimed. These and other objects, features and advantages of the present

invention will become apparent after a review of the following detailed description of the disclosed embodiments and the appended claims.

### BRIEF DESCRIPTION OF THE DRAWING

5        **FIG. 1** is a perspective view of the fin actuation unit of a missile, including four fin actuators, according to an embodiment of the present invention

### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Before explaining the disclosed embodiment of the present invention in detail it is to be  
10 understood that the invention is not limited in its application to the details of the particular arrangement shown since the invention is capable of other embodiments. Also, the terminology used herein is for the purpose of description and not of limitation.

The present invention relates to a fin actuator for a portable missile and a method of using the same. One aspect of the present invention includes a fin or wing actuator that meets very strict  
15 criteria to fit within a compact, portable missile while substantially limiting backlash. Another aspect of the present invention is a method of fin actuation in a portable missile while substantially limiting backlash.

**FIG. 1** illustrates a fin actuator section **10** of a portable missile including four fin actuators of an embodiment of the present invention. Although only three actuators are visible in  
20 **FIG. 1**, it will be appreciated that the actual number of actuators required for a specific missile will be in general evenly spaced around the circumference of the missile body, and that therefore the actuator section **10** in **FIG. 1** includes a fourth actuator which is hidden from view.

Hereinafter, for the sake of simplification, embodiments of one fin actuator of the present invention will be described. The description applies in corresponding manner to the other actuators illustrated. Each of the actuators operates as commanded by a guidance controller (not shown), to thereby rotate its corresponding fin, enabling the missile to maneuver. The guidance control system shall provide a command for rotation of the fin in accordance with known tracking/guidance systems.

The fin actuator section **10** has a means operatively configured for rotating a power shaft **100**, preferably a reversible electric motor, and a power shaft (not shown), that is the motor's output shaft. The power shaft is fixed to a threaded lead screw **120**, preferably by means of a set screw coupler **110**. The lead screw **120** has a lead nut **130** that traverses along the lead screw in response to the rotation of the lead screw **120**. The lead screw **120** is lubricated to enable the lead nut **130** to move smoothly. By rotating the lead screw **120** in forward and reverse directions the lead nut **130** moves in opposite linear directions along the length of the lead screw **120**, thus converting the rotational movement of the power shaft to linear movement. The lead nut **130** is operatively coupled to a crank arm **150** having slots **154** in such a way as to allow it freedom of movement without substantially contributing to the total backlash. Preferably the lead nut **130** includes fixed pins **140** on each side (bottom pin not shown) which slide into the slots **154** of the crank arm **150**. The pins **140** serve to both restrain the lead nut **130** in the crank arm **150**, and as the structural component used to transfer the torque to the crank arm **150**. The crank arm **150** turns in relation to the movement of the lead nut **130**, thereby converting linear movement to the rotational movement of the fin shaft **160**. The crank arm **150** is rigidly attached to the fin shaft **160** thereby the fin shaft **160** is rotated with the rotation of the crank arm **150**, adjusting the fin

(not shown) on the outside of the missile according to the guidance system.

Another aspect of the present invention includes a method for fin actuation, in a portable missile, that substantially limits backlash. An example of the method includes but is not limited to, providing a means operatively configured for rotating a power shaft in a forward direction and a reverse direction, providing a means for converting rotational movement of the power shaft to linear movement via a lead screw fixedly coupled to the power shaft and having a lead nut threadingly engaged moving linearly along the lead screw in relation to the direction of rotation of the power shaft, and providing a means for converting the linear movement to rotational movement of a fin shaft, including operatively coupling the lead nut to a crank arm that is fixedly coupled to the fin shaft, effecting the rotation of the fin shaft according to the linear movement of the lead nut.

#### Example Of An Embodiment Of The Present Invention

In a portable missile fin actuator there exists stringent requirements of size, weight, torque and angle of deflection delivered to the fin shaft, backlash, cost, and ease of construction. One example of a compact, man portable missile requires four fin actuators in its actuator section for maneuverability. It was necessary to construct the missile's fin actuators to meet the following parameters: about 0.1 degree of total backlash as measured at the fin shaft, about 50 ounce-inches (oz-in) torque delivered to the fin shaft, at least about +/- 20 degrees of fin deflection, a maximum actuator section diameter of about 1.7 inches (in), a maximum actuator section length of about 3 inches (in), low cost and easy to assemble. The overall weight of the missile was limited to less than about 5 lbs. An extensive review of existing, available means was performed to find a means

or method to achieve the requirements but none were found.

The requirements were met by an actuator of an embodiment of the present invention as described above. The power shaft consists of the motor output shaft of a reversible, brushless DC motor rated at 50 volts (specifically an API motor, model number B0508) with a feedback position  
5 sensor installed to note the position of the fin at any moment. This motor was selected because of its very low internal backlash and its torque output. The lead screw is attached to the motor output shaft by a two set screw coupler. The size of the lead screw is 3 mm in diameter with a 0.5 mm lead or pitch. The lead screw material is type 304 annealed stainless steel. The lead screw passes through a lead nut which travels linearly forward and back along the lead screw in response to the  
10 direction the lead screw is rotated by the motor. The lead nut material is SAE 660 bearing bronze. The thermal expansion characteristics of the lead screw and the lead nut are comparable, therefore the contribution to the total backlash due to thermal expansion was negligible. The lead screw and the lead nut were lubricated with a dry film lubricant that added a negligible amount of thickness to the surfaces allowing a very close fit of the parts and limiting total backlash. The lubricant used was  
15 Dicronite™ (meets military specification DOD-L-85645A type 1).

A crank arm is driven by the lead nut. The lead nut has 2 pins machined on each end which serves to transfer the motion and torque to the crank arm. The crank arm has slots which allow the pins to traverse the length of the arm as it goes through its rotational movement. The crank arm is rigidly attached to the fin shaft by means of a roll or spring pin. The fin shaft rotates with the crank  
20 arm.

It is noteworthy that the specific total backlash requirements were met by this actuator by constructing and coupling so as to provide for close tolerances of the parts, using the special



lubricant, and selecting materials such as the bronze lead nut and the stainless steel lead screw. The softer bronze gives way to the stainless steel, acting as when there was more room between the threads or as when more lubrication was present without adding to the total backlash. It is also noteworthy that this actuator is constructed and coupled using parts that are readily assembled or  
5 repaired in the field when the need arises, as well as being easily assembled in a manufacturing situation.

There accordingly has been described a novel fin actuator and a method of fin actuation for a compact, portable missile meeting stringent requirements of size, weight, torque and angle of deflection delivered to the fin shaft, backlash, cost, and ease of construction. The present invention  
10 has the benefit of being simple to assemble as well as providing very close tolerances to meet the backlash requirement. The present invention allows for accurate assembly with minimal labor time or expertise. The present invention contributes to the success of the warfighter in today's conflict scenarios.

Although the description above contains much specificity, this should not be construed as  
15 limiting the scope of the invention but as merely providing an illustration of the presently preferred embodiment of the invention. Thus the scope of this invention should be determined by the appended claims and their legal equivalents.